Headquarters U.S. Air Force

Integrity - Service - Excellence

MAROS - Monitoring and Remediation Optimization System

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Groundwater Services, Inc.
Jan. 31, 2001

Team Members and Funding

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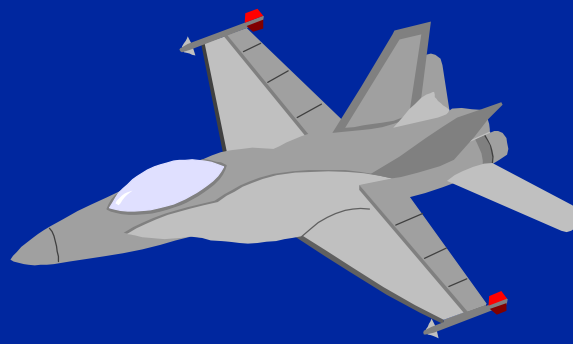
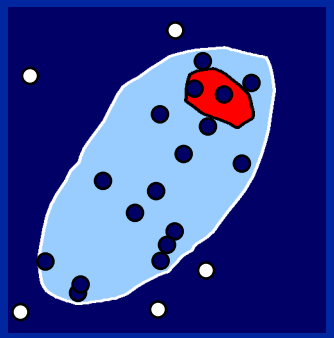
  AFCEE Tech Transfer Division



Funded by AFCEE Tech Transfer Division

Long-Term Monitoring Calculus

	Number of Sites		*Cost Per Well*		*Number of Wells*		*Frequency, Duration of Sampling*
LTM Cost ($) =		X		X		X	
Addressed By This Tool?	***NO***		***NO***		***YES***		***YES***

TWO LONG-TERM MONITORING PLANS

	$	NPV $
A. CONVENTIONAL PLAN:	**$ 1,200 K**	**$ 615 K**
10 Wells Quarterly for 30 Years	↓	↓
B. OPTIMIZED PLAN:	**$ 360 K**	**$ 185 K**
Six Wells Twice/Yr for 30 Years		

COST SAVINGS: 70%

Current LTMP Negotiation Process

Owner Collect, Analyzes Site Data

What are conditions at site?

Owner Submits Multiple Reports Over Several Years

What are the data saying?

Owner, Regulators Negotiate Long Term Monitoring Plan

What is the bottom line on this plume?

Obstacles to Effective Negotiations

- *Historical data not all in one place - it is difficult to get "birds-eye view" of plume over time.*
- *Trends are not always clear due to data scatter.*
- *No formal mechanism to say which wells aren't needed.*
- *No mechanism to keep regulators updated on LTMP results.*

MAROS Benefits

- *Storehouse/presentation tool for site historical data .*
- *Provides statistical information on trends.*
- *Tool for identifying “redundant” wells.*
- *Help “optimize” sampling frequency, number of wells.*
- *New data goes in, updated report automatically comes out.*

MAROS Caveats

- *Microsoft Access database - needs to be maintained .*
- *Best for small to medium sites (<50 wells).*
- *No real mapping capability at this time.*
- *Can’t fix bad plumes.*

Key Concept: Knowledge of Plume Trend Can Translate into LTMP Cost Savings

Example 1:

expanding, chlorinated, fast gw

More Intensive LTMP: MORE wells, MORE frequent

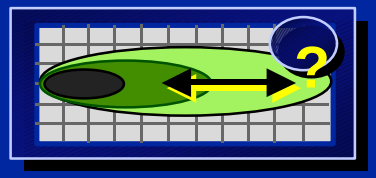
Example 2:

shrinking, BTEX slow gw:

More Intensive LTMP: FEWER wells, LESS frequent

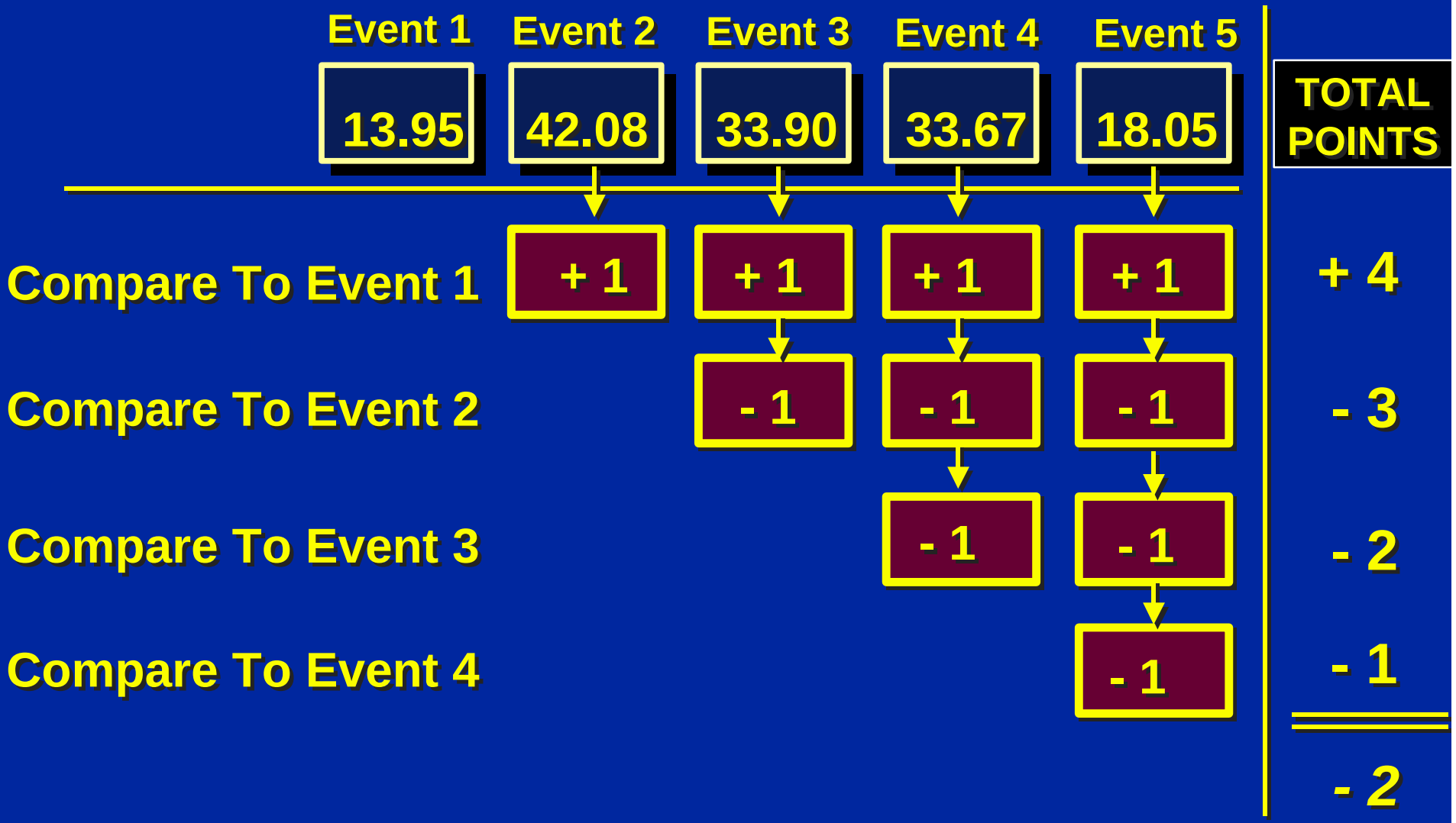
MAROS provides a first-cut blueprint for a LTMP

MAROS Software - Key Themes

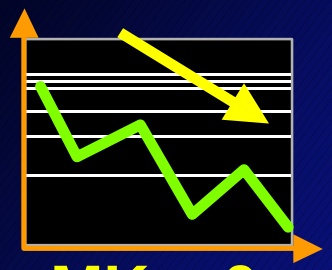
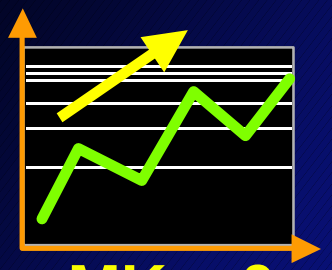
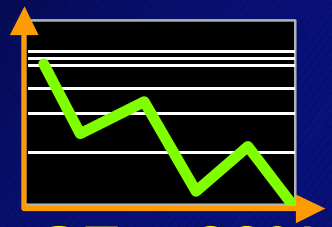
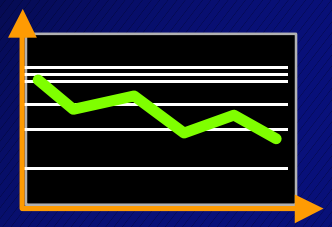
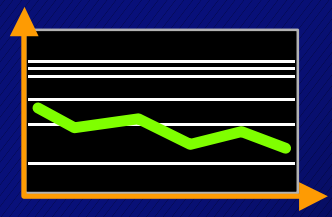
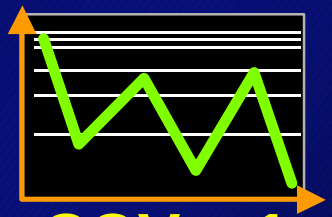


- **AFCEE Tool: Keep it simple & free**
- **"Evergreen": Can update data, develop new modules**
- **Based on Lines of Evidence**
  - ***Primary LOE:* Conc. vs. Time Data, Simple Stats**
  - ***Secondary LOE: Simple Models, Empirical Data***

Mann-Kendall Test: Approach



Interpretation of Mann-Kendall Tests

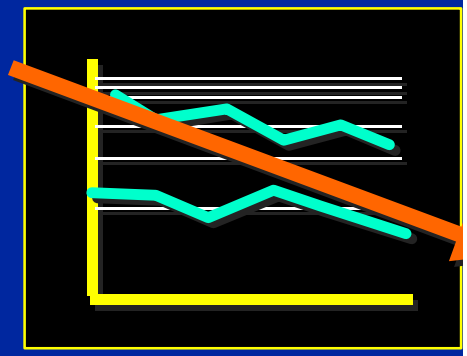
MK Statistic (S)	 **Decreasing Trend** **MK < 0**	 **Increasing Trend** **MK > 0**
Confidence Factor (CF)	 **Strong Trend** **CF > 90%**	 **Weak Trend** **CF < 90%**
Coefficient of Variation (COV)	 **Stable Trend** **COV < 1**	 **Fluctuating Trend** **COV > 1**

Mann-Kendall Test Results: Interpretation

		Confidence Factor		
		CF > 95%	90%<CF<95%	CF < 90%
Mann-Kendall Statistic	MK < 0	Decreasing	Prob. Decreasing	COV < 1 *Stable*
				COV > 1 *No Trend*
	MK > 0	Increasing	Prob. Increasing	No Trend

Linear Regression Analysis

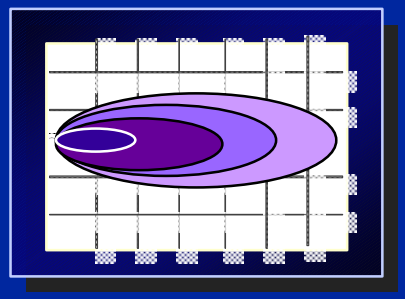
- **Parametric test; assumes log-normal distribution**
- **Minimum amount of data for meaningful results**
- **Returns Log Slope regarding trend**
  - **Negative number: *declining trend***
  - **Positive number: *increasing trend***
- **Some interpretation of what Log Slope means**



Lines of Evidence

- ***Primary Lines of Evidence***

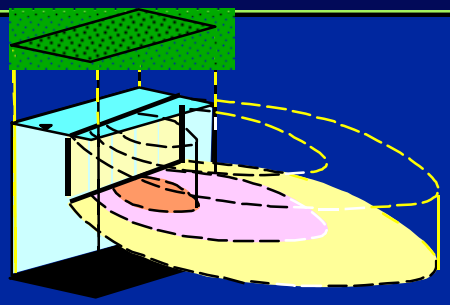
- **Secondary Lines of Evidence (Optional Lines of Evidence)**



Secondary Line of Evidence: Models

BIOSCREEN

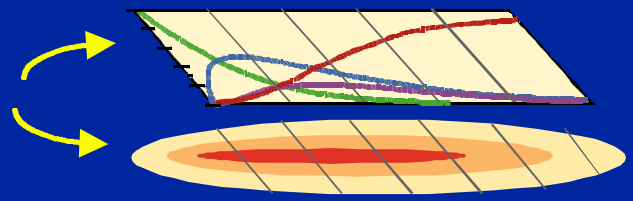
- Petroleum Hydrocarbon Sites – BTEX
- Biodegradation:
  - *1st Order Decay or*
  - *Electron Acceptors*



www.epa.gov/ada/kerrlab.html

BIOCHLOR

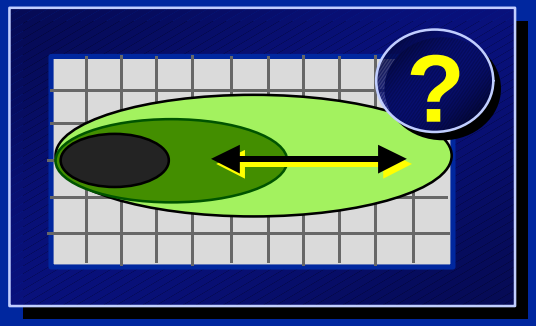
- Solvent Sites
- More Complex Biodegradation:
  - *Sequential Reactions*
  - *Different Zones*



www.gsi-net.com

Secondary Line of Evidence: Models

How to use a model to determine plume stability



Step 1

Calibrate model to existing monitoring data.

Step 2

Increase time to 25 years in the future.

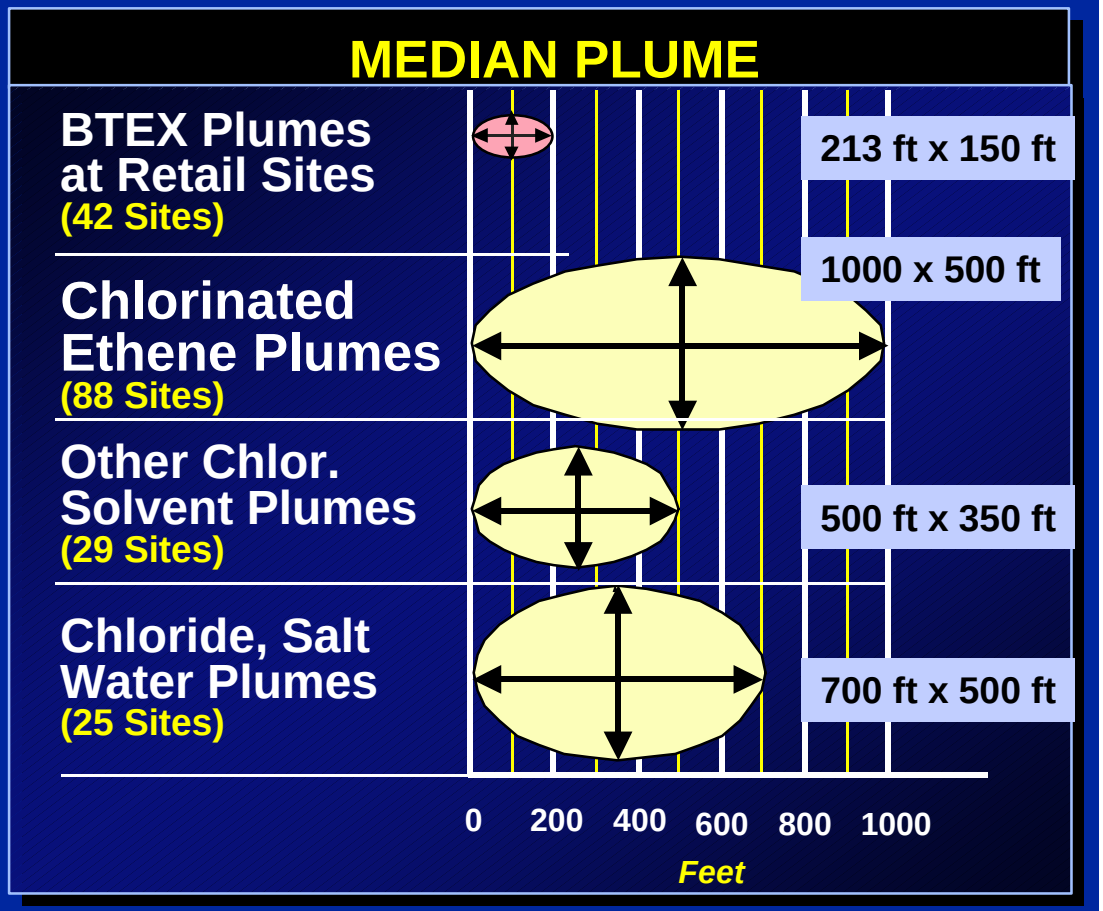
Step 3

See if plume gets larger.

Secondary Line of Evidence: Empirical Data

"Plume-a-thon" (multiple-site statistical) studies:

- **BTEX plumes in California, Texas, Florida, and nationwide**
- **MTBE plumes in California and Texas**
- **Chlorinated solvent plumes nationwide: LLNL and AFCEE**

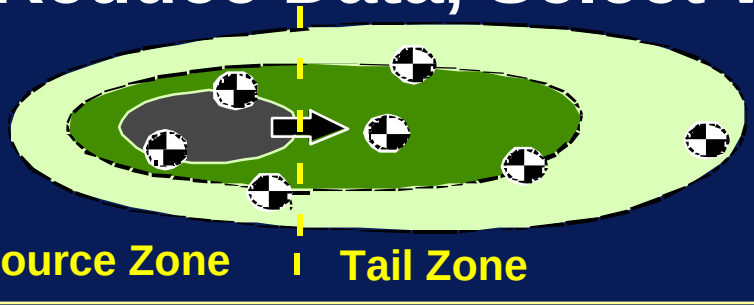


Newell and Connor, API, 1998

MAROS Flow Chart

1

Enter Data, Reduce Data, Select Wells



2

Identify Site Constituents of Concern (COCs).

3

Analyze Lines of Evidence (LOEs) for Plume Stability (by well and by COC)

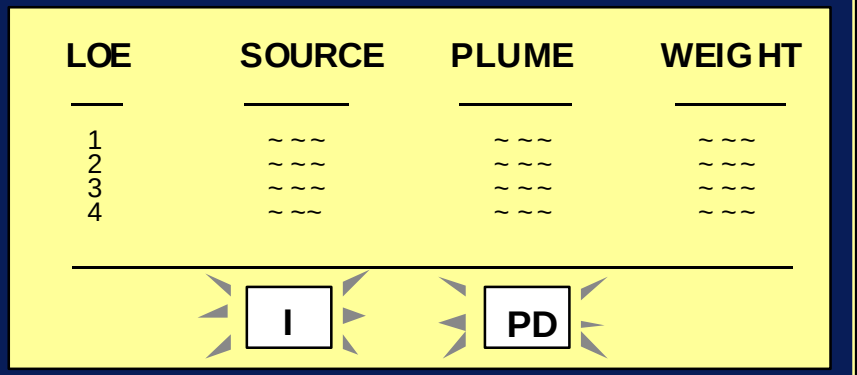
- Increasing (I)
- Probably Increasing (PI)
- No Trend (NT)
- Stable (S)
- Probably Decreasing (PD)
- Decreasing (D)

LTMP DSS Flow Chart

4

Determine General Trend for Each Well Based On All LOE's

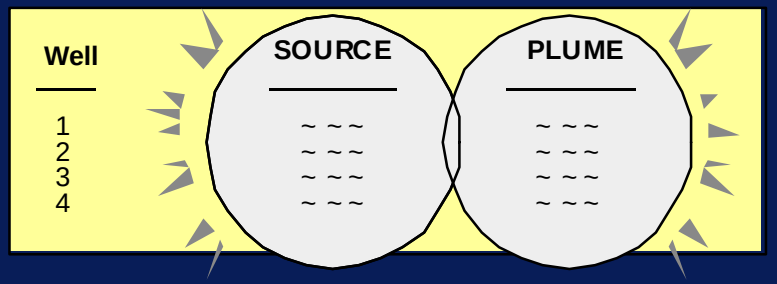
"Lump Lines of Evidence"



5

Determine General Trend for Source and Tail

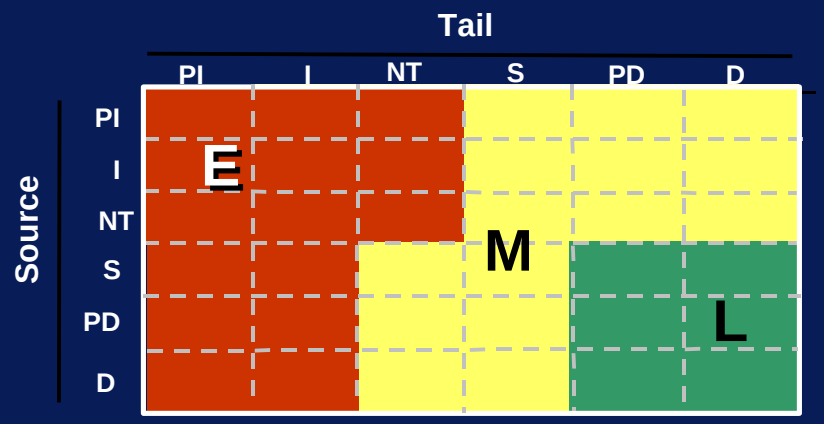
- Increasing (I)
- Probably Increasing (PI)
- No Trend (NT)
- Stable (S)
- Probably Decreasing (PD)
- Decreasing (D)



"Lump Wells" in Source and Tail Zone

MAROS Flow Chart

6 **Determine LTMP Monitoring Category for COC By Source / Tail**



Monitoring Categories

- E: Extensive
- M: Moderate
- L: Limited

7 **Specify Preliminary Monitoring System Optimization Results based on Monitoring category and site-specific parameters.**

- Well Density, Sampling Frequency, Sampling Duration

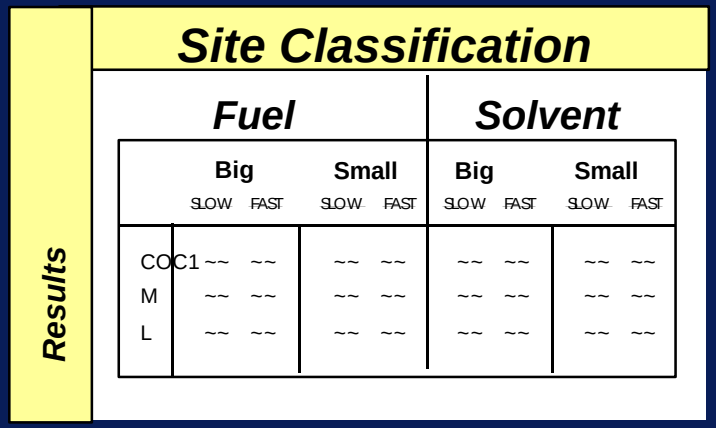
Result: Site-Specific LTMP Plan

8

1 page Report with Preliminary Monitoring System Optimization Results for each COC.

Results by COC

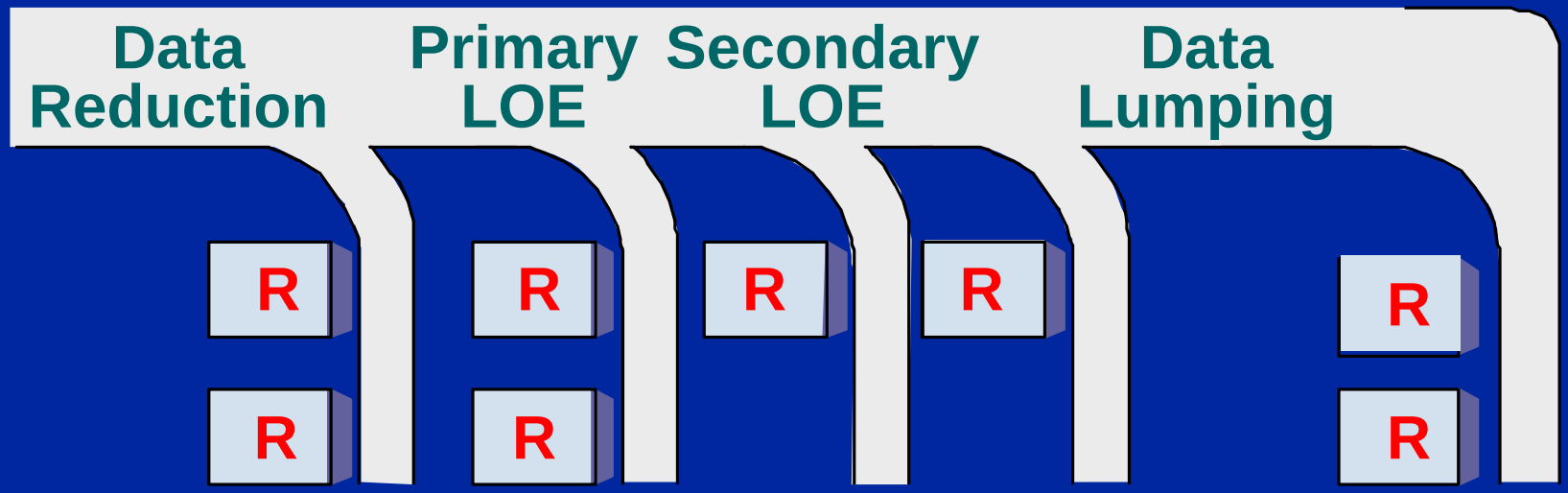
- Source Stability
- Tail Stability
- Monitoring Category
- Well Density
- Sampling Frequency
- Sampling Duration



Sampling Frequency: Decision Matrix

Time To Receptor:	*Monitoring System Category*		
	E	**M**	**L**
Close (TTR < 2 yrs)	**Quarterly**	**Biannually (6 months)**	**Annually**
Med. (2<TTR<5 yrs)	**Biannually (6 months)**	**Annually**	**Annually**
Far (TTR > 5 yrs)	**Annually**	**Annually**	**Biennially (2 years)**

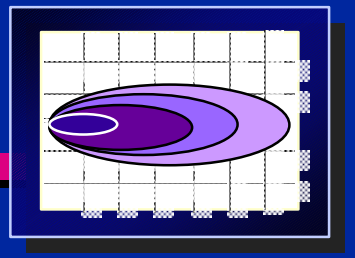
MAROS Road Map



Degree of Assumptions

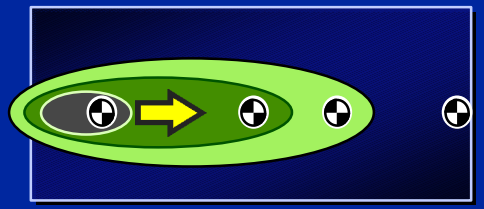
LOW MEDIUM HIGH

Sampling Optimization



More Complex (Optional) Methods:

1. **Sampling Location (Delaunay Triangulation)**

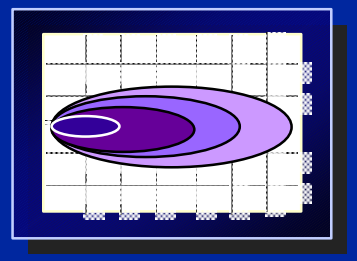


2. **Sampling Frequency (Modified CES)**

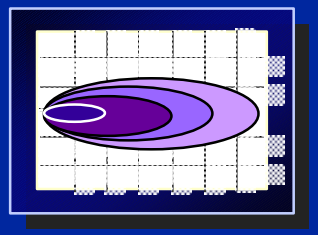
Sampling Location Optimization

Significance of current sampling locations in monitoring network (eliminate "redundant" wells)

- **Delaunay Triangulation – area concentrations**
- **Does estimated concentration change if well is removed?**
- ***Utility for evaluating well removal***



MAROS Software Tool: Features

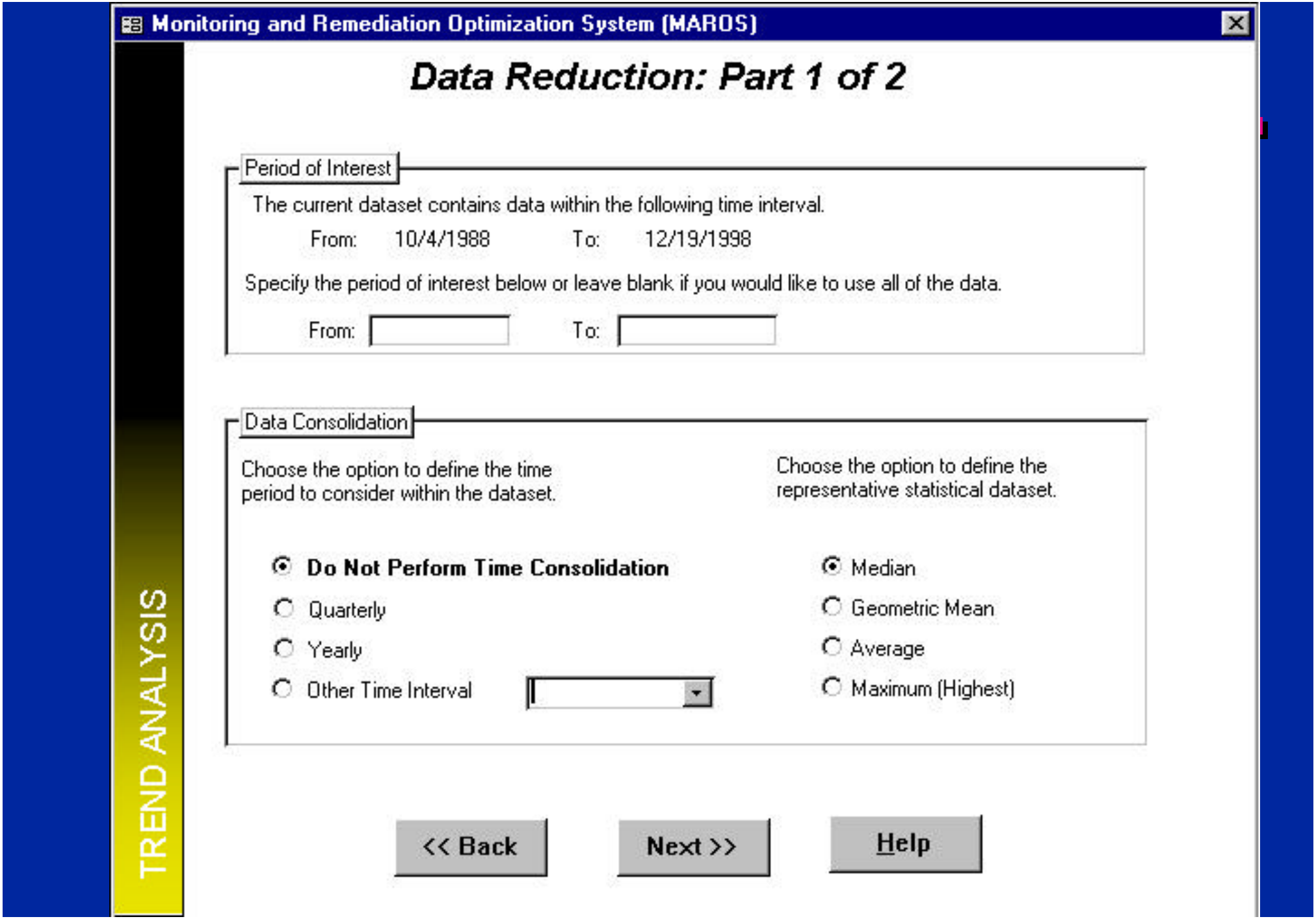


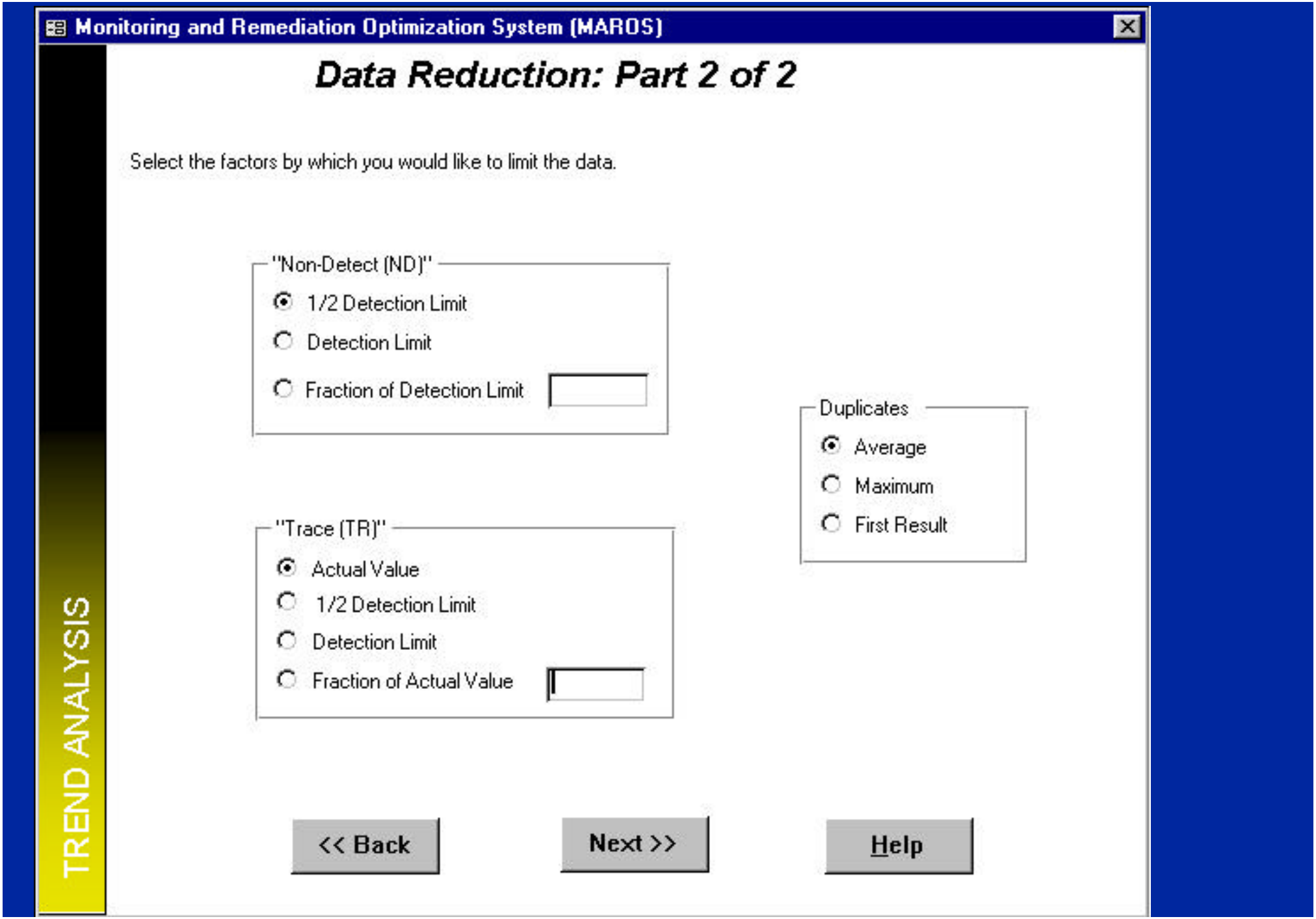
- Evergreen Database - based on MS Access
- Flexible import features (Excel, ERPIMS, etc.)
- Data Reduction Features
- C vs. T Plotting, Mann-Kendall, Linear Regression
- Input of Modeling, Empirical Evidence
- Evaluates Sampling Frequency, Well Density
- “Get off at any stop” Approach
- New version: Power Analysis, Moments, Graphics

AFCEE Tool - FREE at www.gsi-net.com

MAROS

Monitoring and Remediation Optimization System (MAROS)
HQ Air Force Center for Environmental Excellence
Monitoring and Remediation Optimization System (MAROS)
Software Tool
Data management tool for analyzing and optimizing groundwater monitoring programs.
User Name:
Jim Gonzales
Project Name:
Air Force Base 1
Start
Copyright © 2000, Air Force Center for Environmental Excellence


Monitoring and Remediation Optimization System (MAROS)
Data Reduction: Part 1 of 2
TREND ANALYSIS
Period of Interest
The current dataset contains data within the following time interval.
From: 10/4/1988 To: 12/19/1998
Specify the period of interest below or leave blank if you would like to use all of the data.
From:
To:
Data Consolidation
Choose the option to define the time period to consider within the dataset.
Do Not Perform Time Consolidation
Quarterly
Yearly
Other Time Interval
Choose the option to define the representative statistical dataset.
Median
Geometric Mean
Average
Maximum (Highest)
<< Back
Next >>
Help


Monitoring and Remediation Optimization System (MAROS)
Data Reduction: Part 2 of 2
Select the factors by which you would like to limit the data.
"Non-Detect (ND)"
1/2 Detection Limit
Detection Limit
Fraction of Detection Limit
"Trace (TR)"
Actual Value
1/2 Detection Limit
Detection Limit
Fraction of Actual Value
Duplicates
Average
Maximum
First Result
TREND ANALYSIS
<< Back
Next >>
Help

Monitoring and Remediation Optimization System (MAROS)

TREND ANALYSIS

Mann Kendall Statistics

The Mann-Kendall Analysis is used for analyzing a single groundwater constituent, multiple constituents are analyzed separately. Each "tab" below shows the statistics for one constituent.

See manual text or "Help" for description of trend determination method.

BENZENE | ETHYLBENZENE

Statistical Analysis Results. Last column is the result for the trend.

Well	S/T	COV	MK (S)	Confidence in Trend	Concentration Trend
MW-15	S	0.000	0	42.3%	S
MW-14	S	1.606	-50	99.9%	D
MW-13	S	1.106	-53	99.8%	D
MW-12	S	1.591	-68	100.0%	D
MW-1	S	1.701	-15	98.5%	D
MW-8	T	0.985	-11	70.5%	S
MW-7	T	0.249	-7	62.6%	S
MW-6	T	0.000	0	47.8%	S

Note: Increasing (I); Probably Increasing (PI); Stable (S); Probably Decreasing (PD); Decreasing (D); No Trend (NT); Not Applicable (N/A); Source/Tail (S/T); COV (Coefficient of Variation); MK(S) Mann-Kendall Statistic

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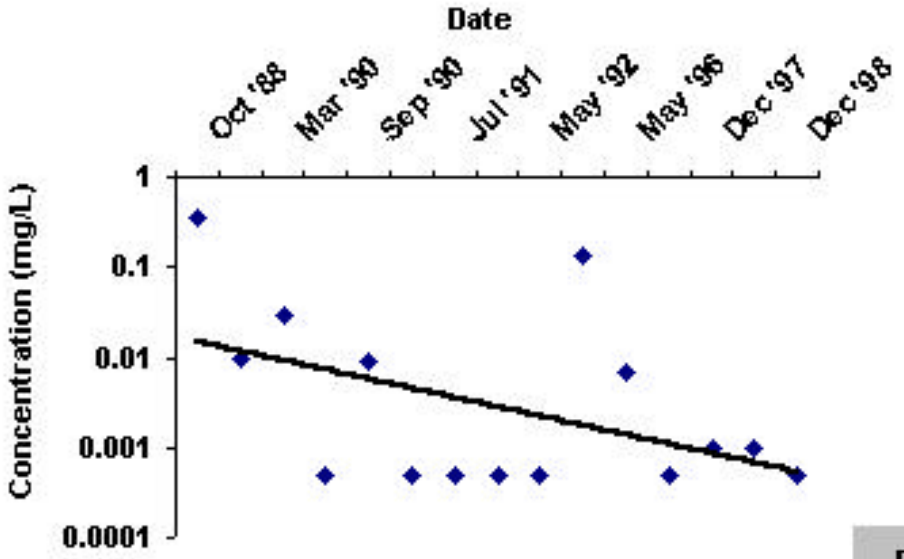
Monitoring and Remediation Optimization System (MAROS)

TREND ANALYSIS

Linear Regression Plot

Select a well and chemical below to graph. The concentration trend result in the box below reflects the chemical and well chosen to be graphed.

Select: **Well** MW-4 **Chemical** ETHYLBENZENE



Graph Type
- (•) Log
- ( ) Linear

Graph

COV: 2.59E+00

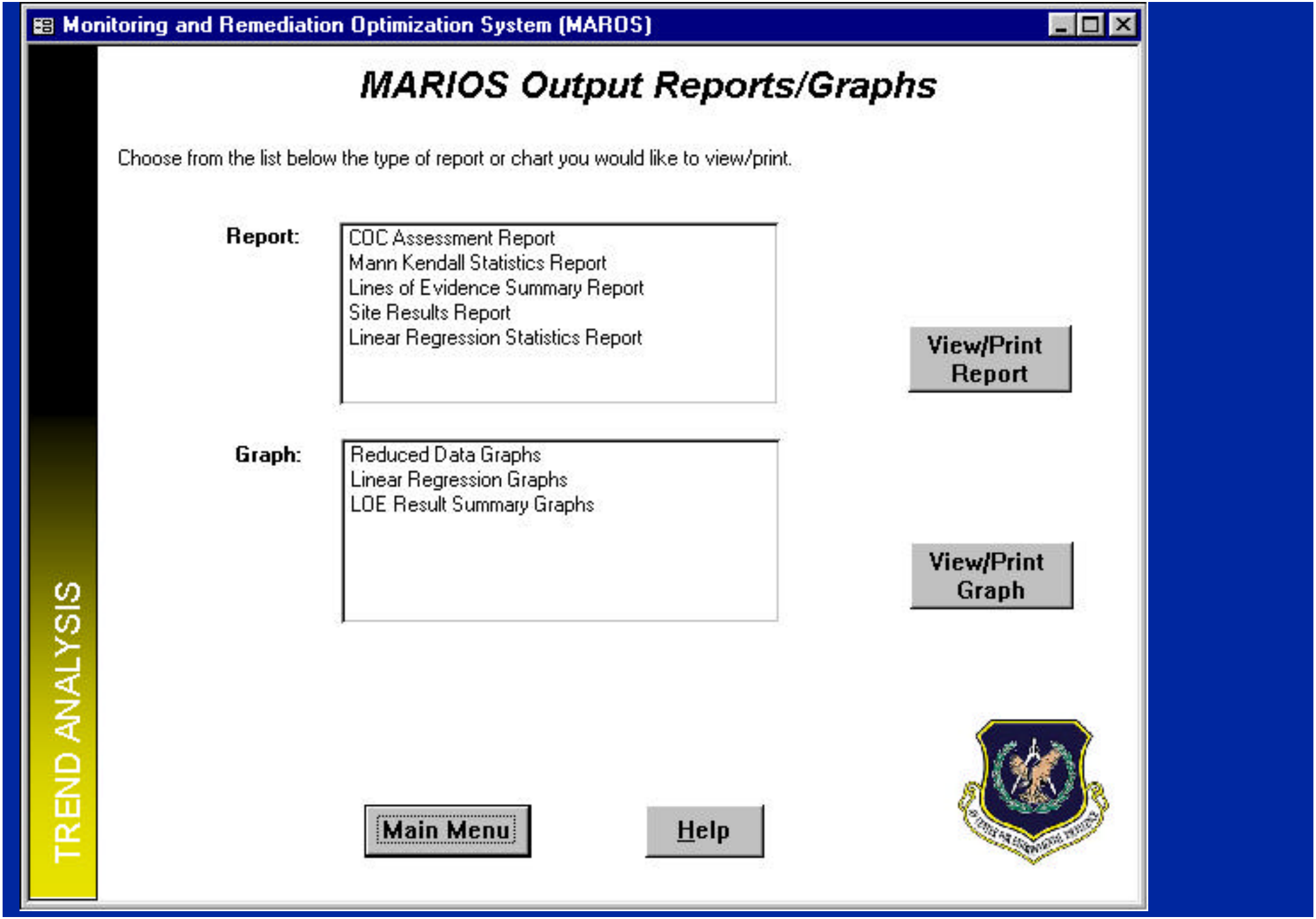
Confidence in Trend: 91.9%

Ln Slope: -6.60E-04

Print

Concentration Trend: PD

<< Back | Next >> | Help


Monitoring and Remediation Optimization System (MAROS)
MARIOS Output Reports/Graphs
Choose from the list below the type of report or chart you would like to view/print.
Report:
COC Assessment Report
Mann Kendall Statistics Report
Lines of Evidence Summary Report
Site Results Report
Linear Regression Statistics Report
View/Print Report
Graph:
Reduced Data Graphs
Linear Regression Graphs
LOE Result Summary Graphs
View/Print Graph
TREND ANALYSIS
Main Menu
Help